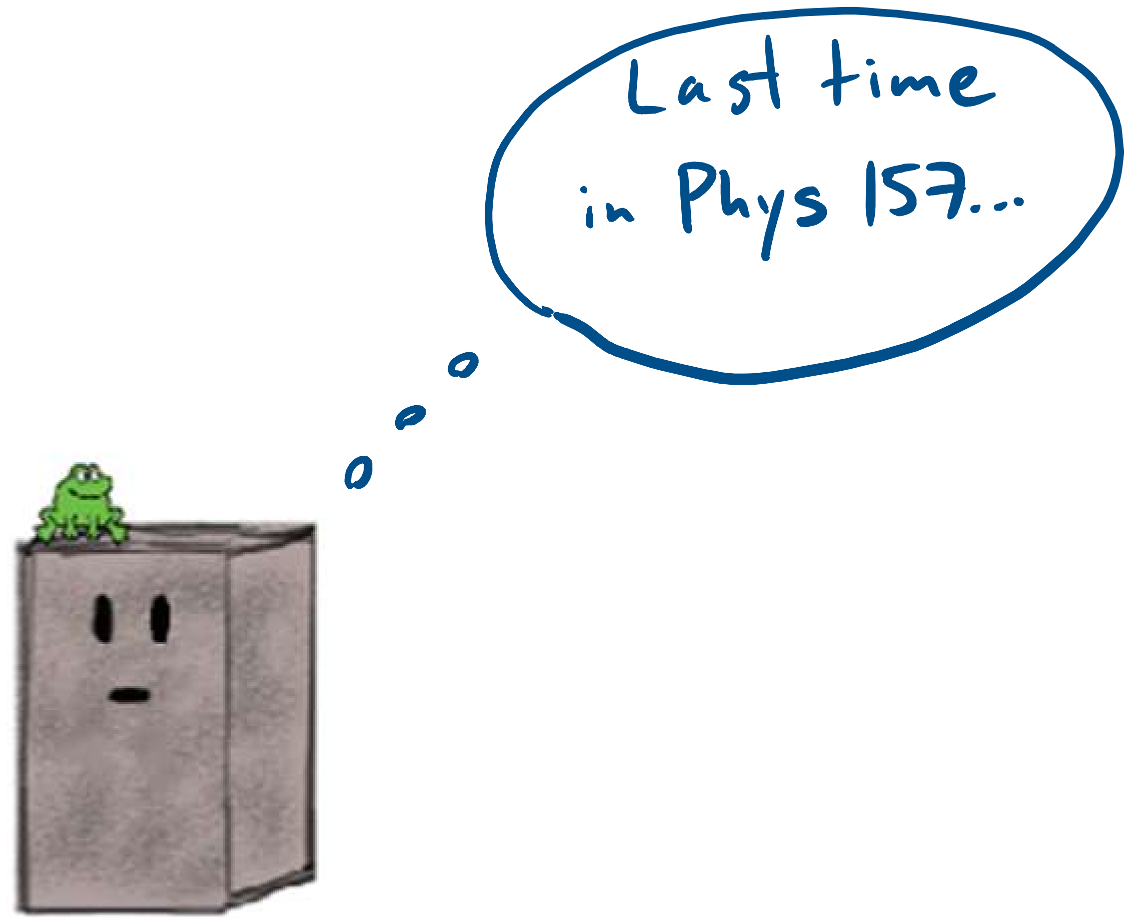
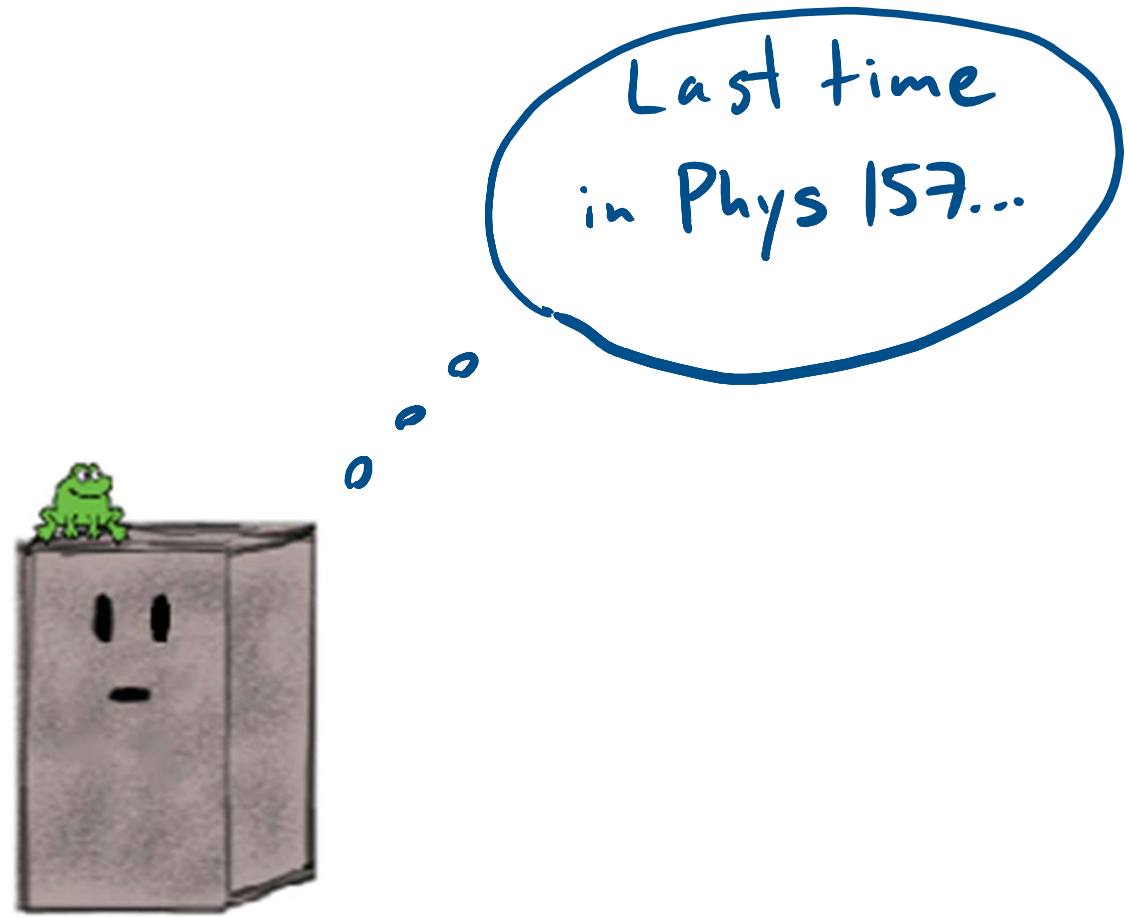
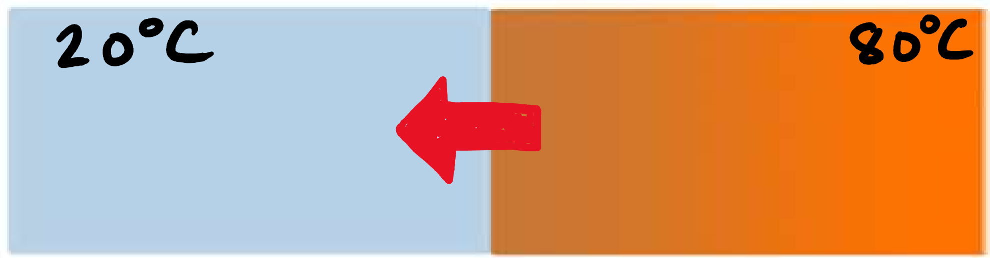

Last time
in Phys 157...

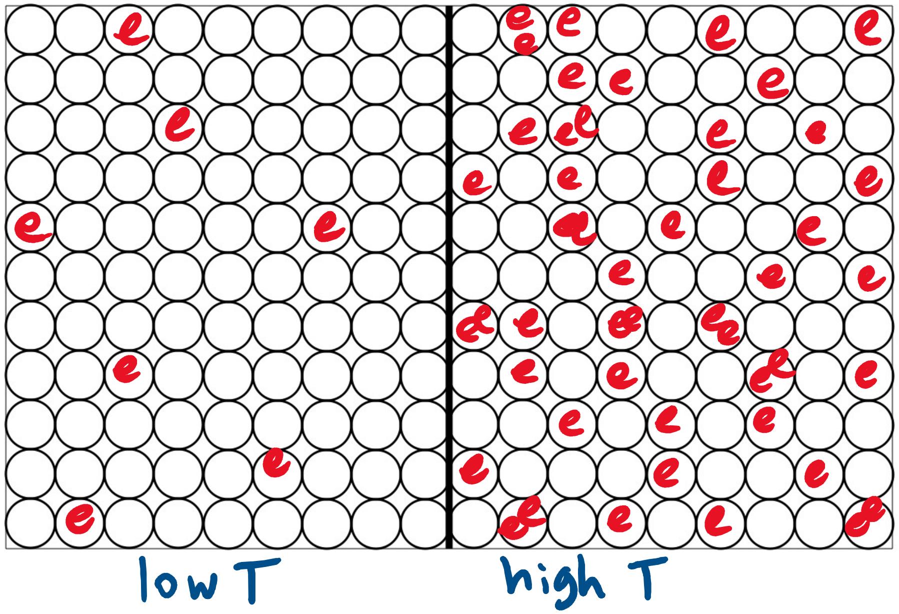

Last time in Phys 157...

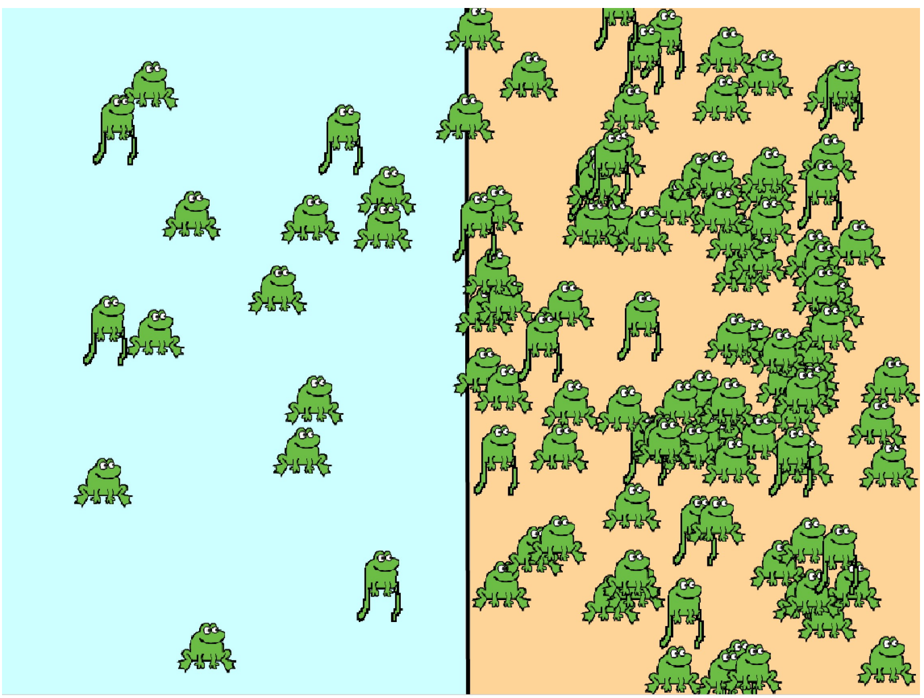


Why does heat always flow from hot objects to colder objects?

Why can't we make a refrigerator that requires no work done?

Why can't we make an engine that converts heat completely into work?





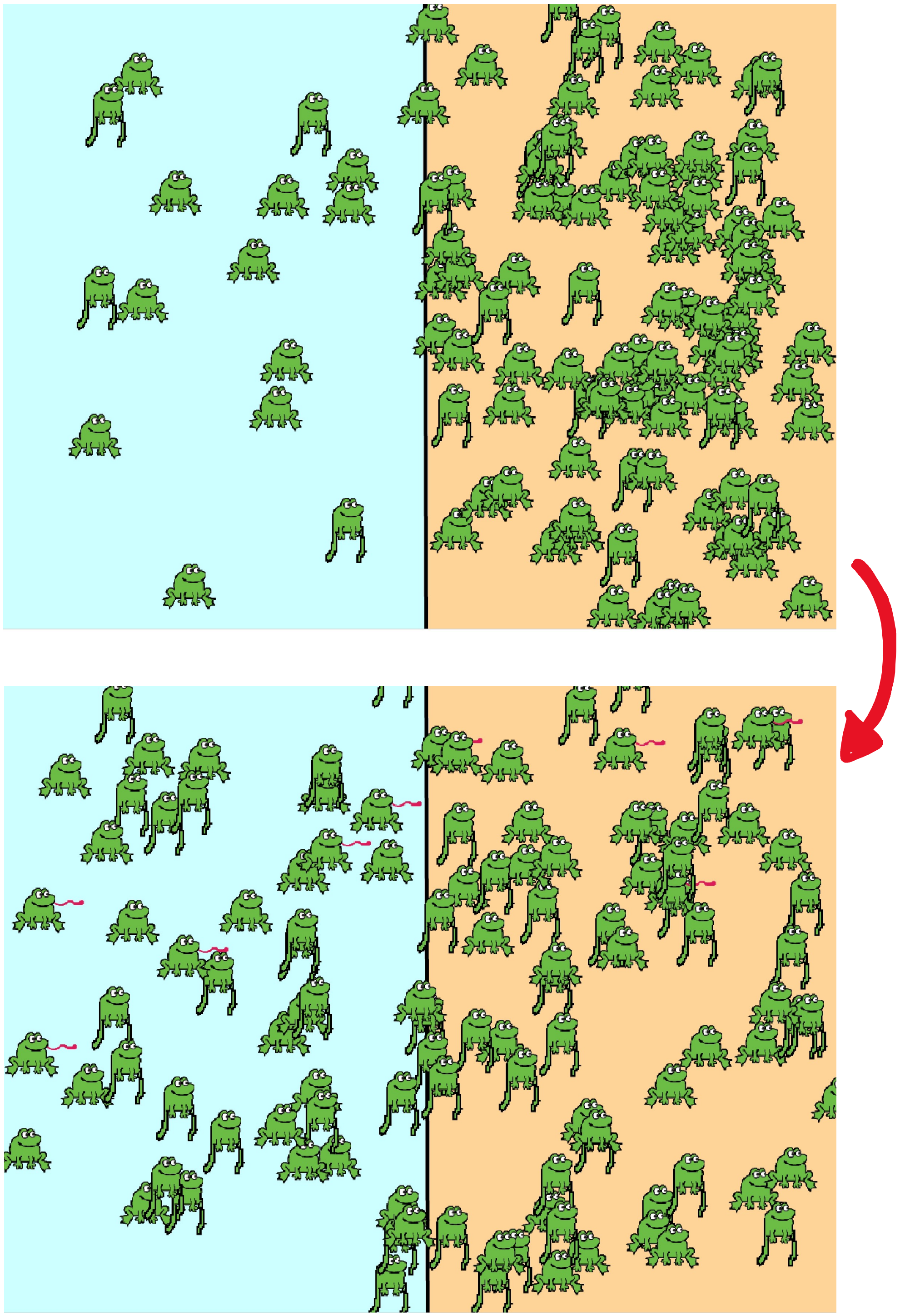
Analogy:

Frogs = energy

Conserved + move randomly

density of frogs = temperature

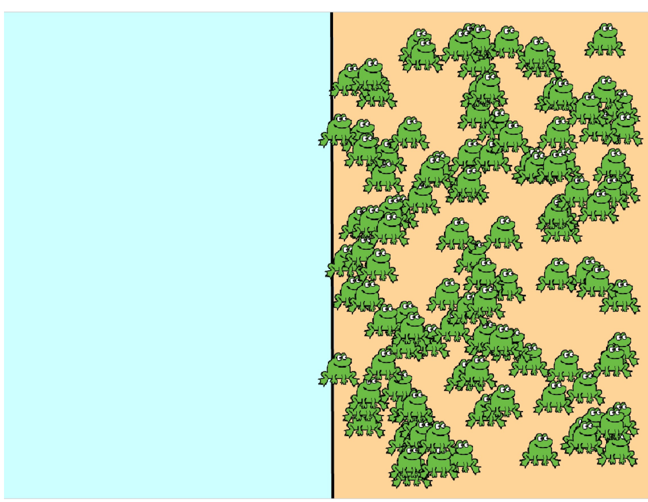
proportional to energy per molecule



If the frog motion is random, why do we see a net motion of frogs from high density to low density?

As time passes, we move between possible configurations of frogs.

All specific configurations are equally likely



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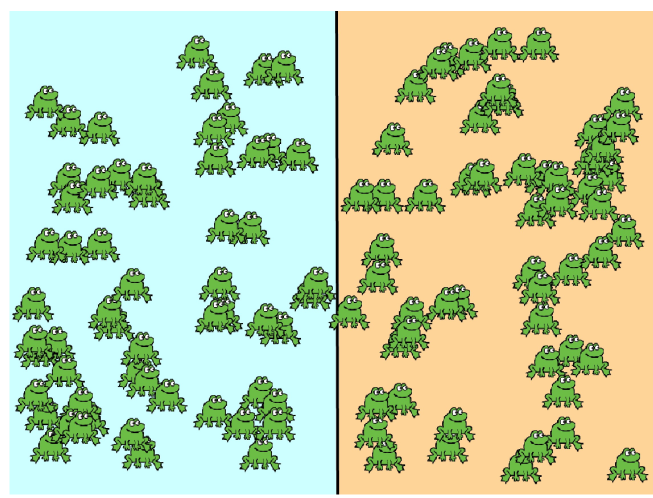
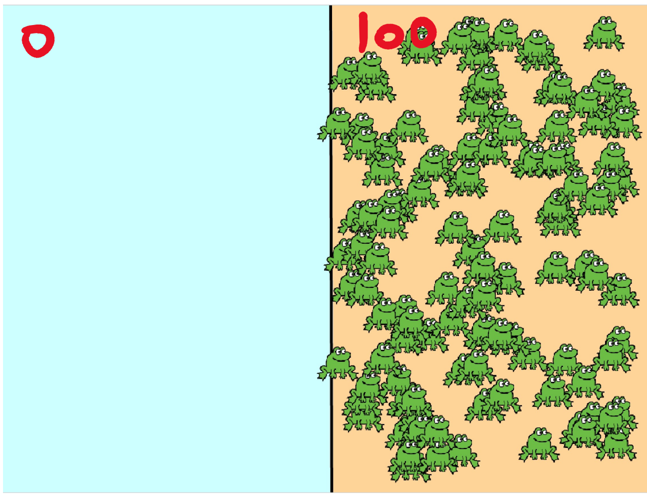
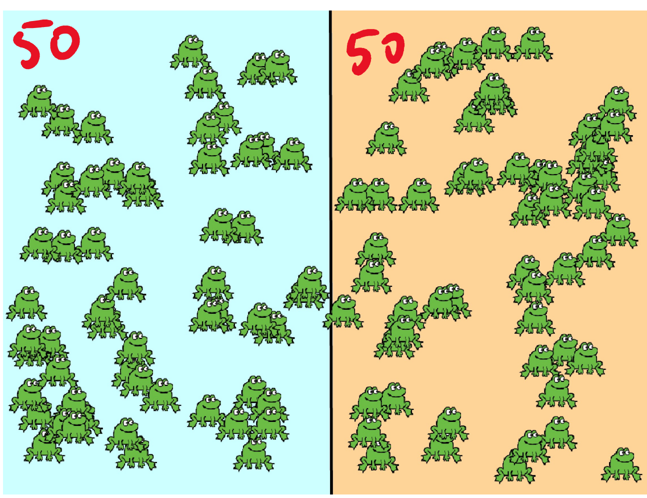


BUT...



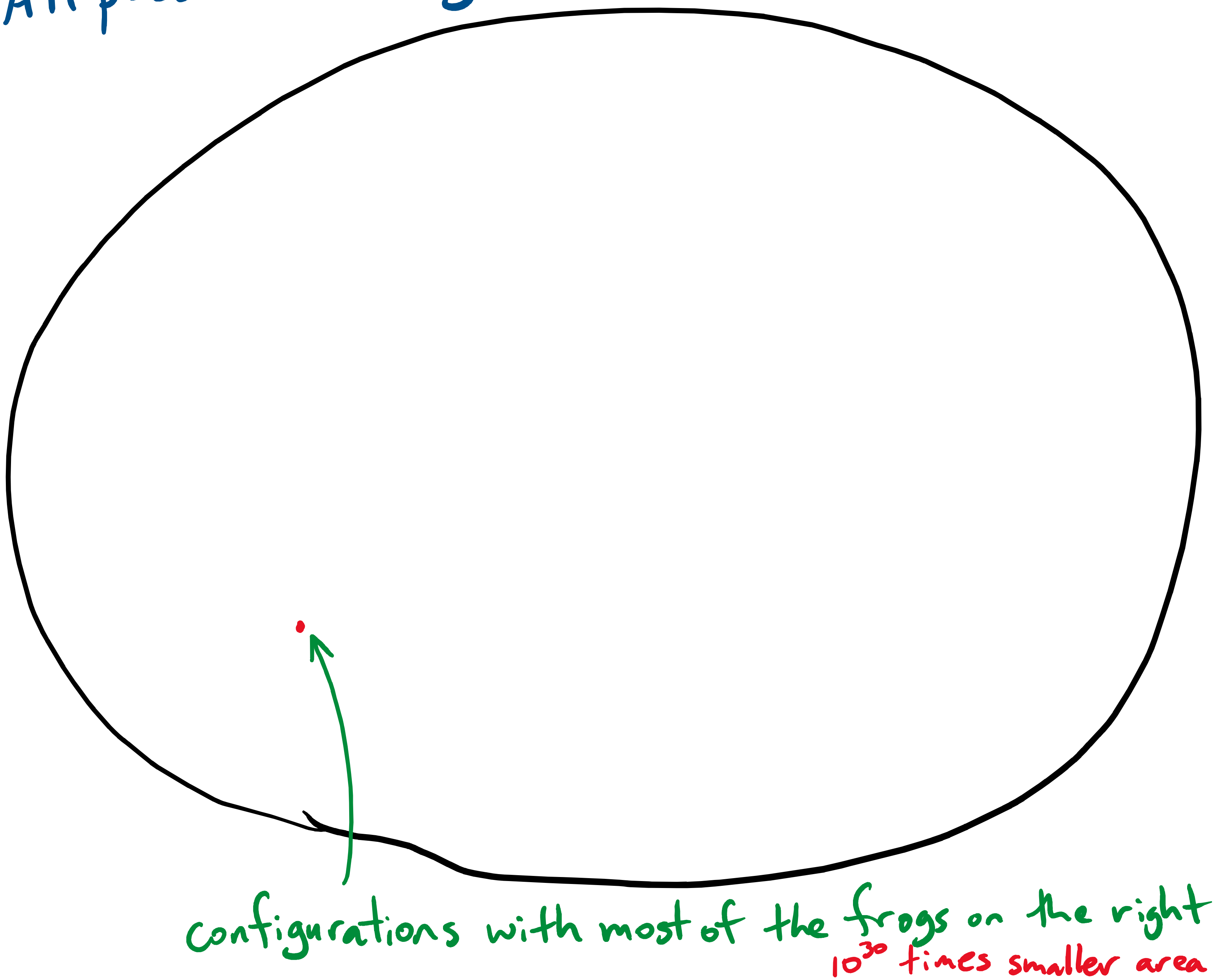
10^{500} configurations like this

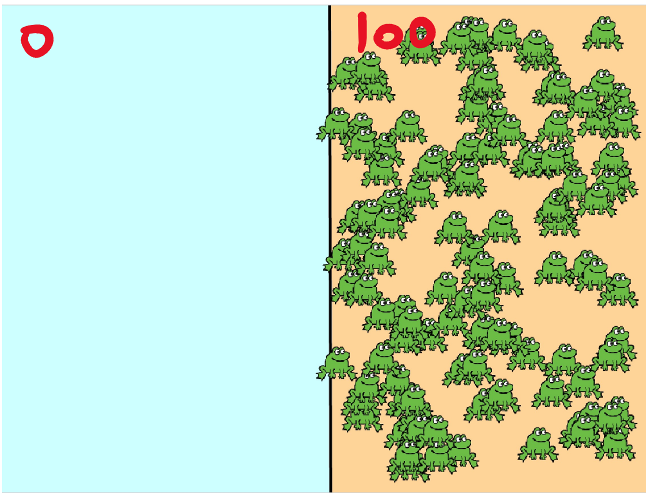


10^{530} configurations like this

(10^5 possible pixel locations for each frog)

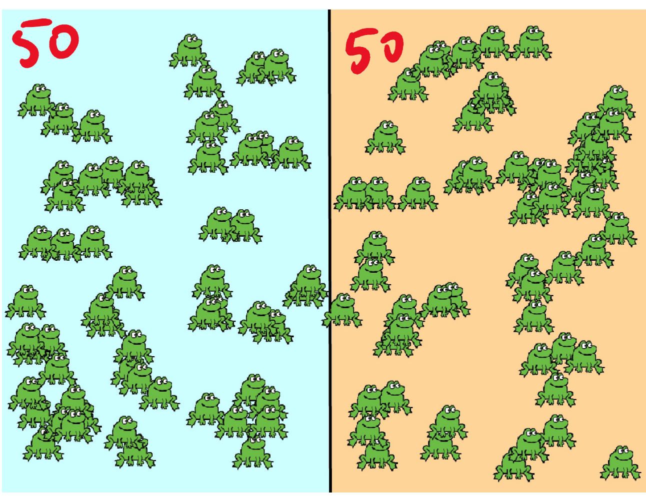
All possible configurations of frogs:



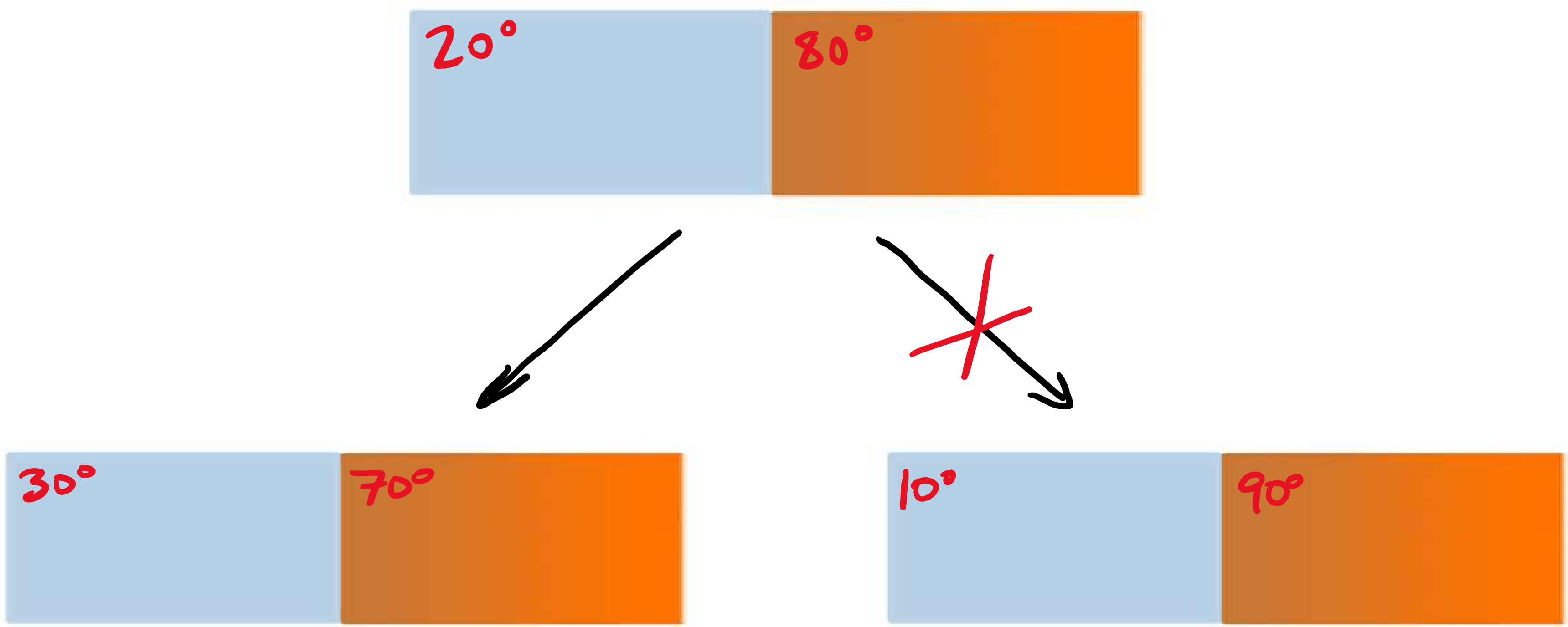


If we start here

After a while, we are 10^{30} times more likely to end up in a (50,50) configuration than a (0,100) configuration.



If we start here:



$10^{1000\,000\,000\,000\,000\,000\,000000}$

times more likely to end up here.

Define ENTROPY of a macroscopic configuration

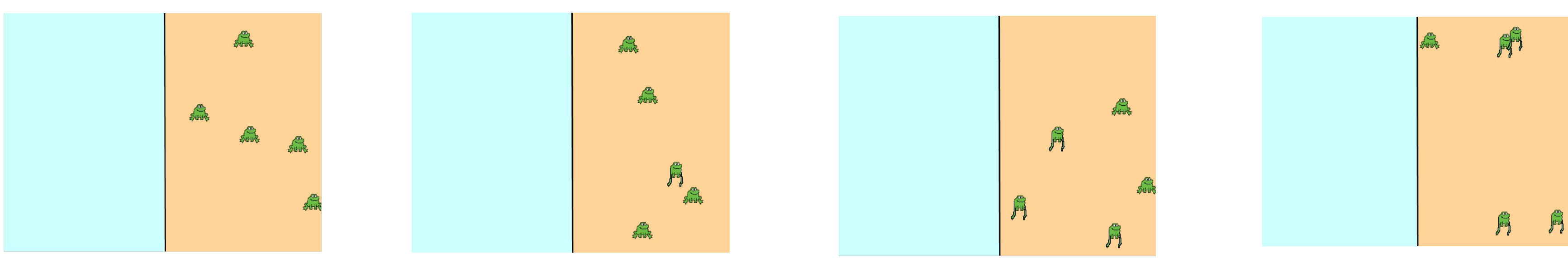
e.g.
(30,70) distribution
of frogs

e.g.2: gas with
pressure P, volume V,
temperature T

$$S = \text{const} \times \ln[N]$$

number of microscopic
configurations of this
type

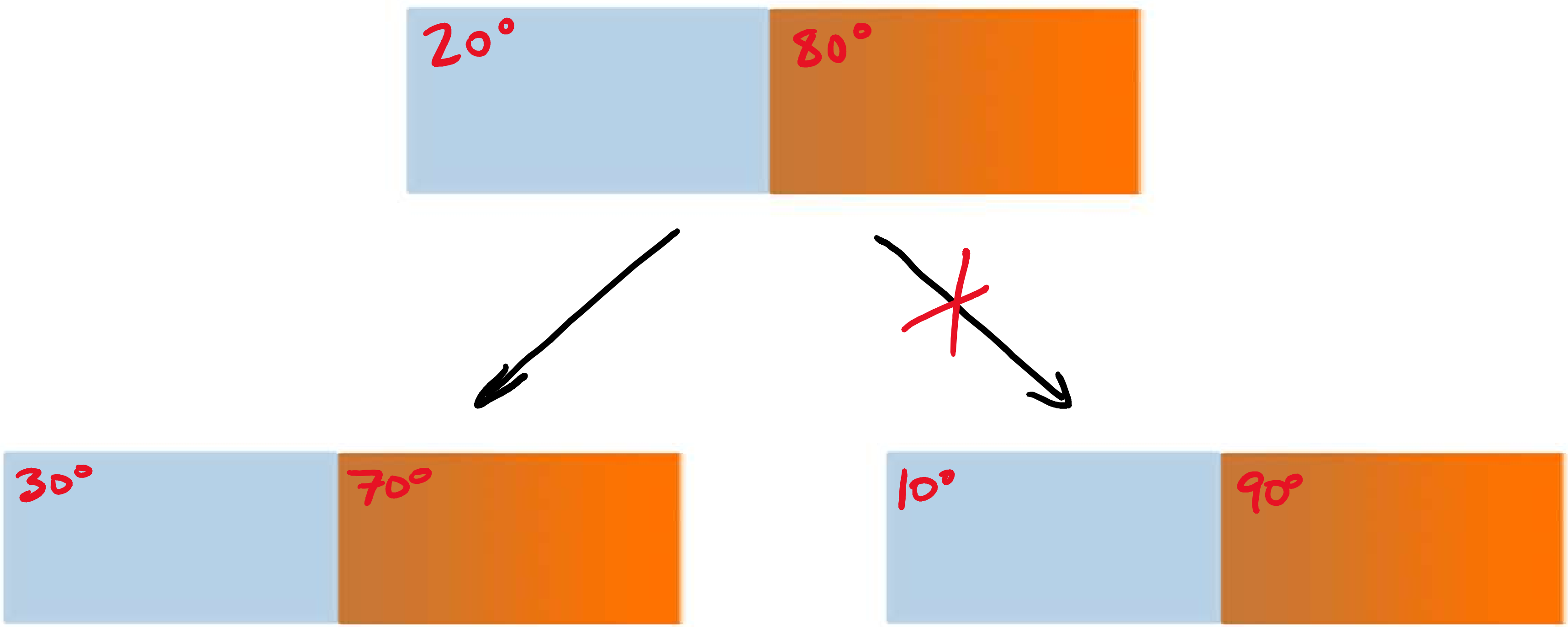
some microscopic configurations of frogs with macroscopic configuration (0,5)



2ND LAW OF THERMODYNAMICS:

Total entropy never decreases.

↳ probability of decrease is unimaginably small



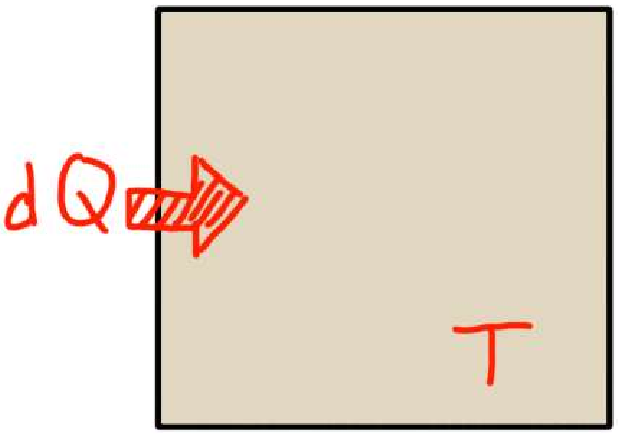
higher entropy

= far more states with these Ts

lower entropy

= far less states w. these Ts.

ENTROPY : macroscopic definition



$$dS = \frac{dQ}{T}$$

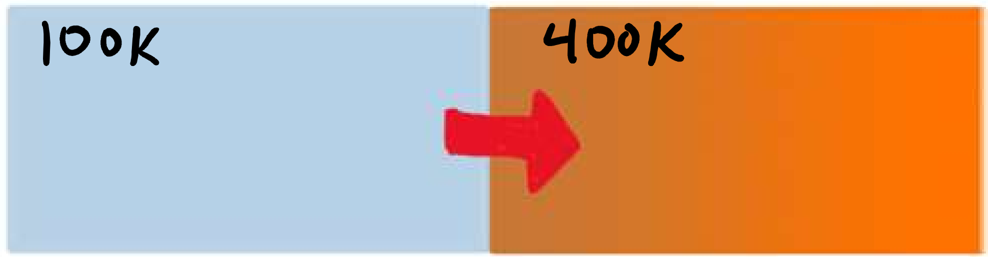
heat added

change in entropy

Amazing result:

we can prove this from the microscopic definition of S.

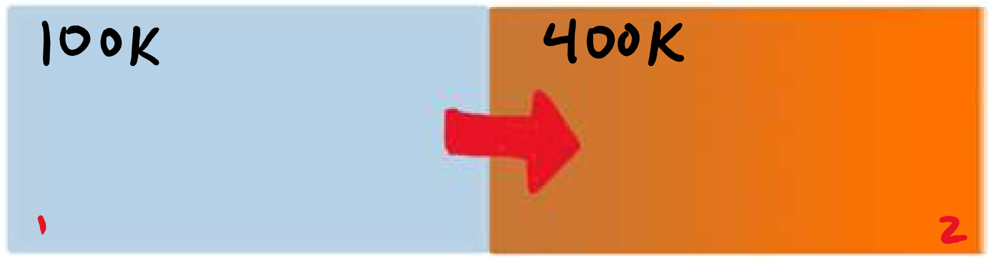
* see bonus video * https://www.youtube.com/watch?v=t7gyi8NhgYg



Suppose that we had 1J of energy flow from the cold object to the hotter object. What would be the change in entropy of the whole system?

A) -0.0125 J/K
B) -0.0075 J/K
C) 0
D) 0.0075 J/K
E) 0.0125 J/K

$$dS = \frac{dQ}{T}$$



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A) -0.0125 J/K
B) -0.0075 J/K
C) 0
D) 0.0075 J/K
E) 0.0125 J/K

Have $dS = dS_1 + dS_2$

$$= \frac{dQ_1}{T_1} + \frac{dQ_2}{T_2}$$

$$= \frac{-1J}{100K} + \frac{1J}{400K}$$

$$= -0.0075\ J/K$$

BAD

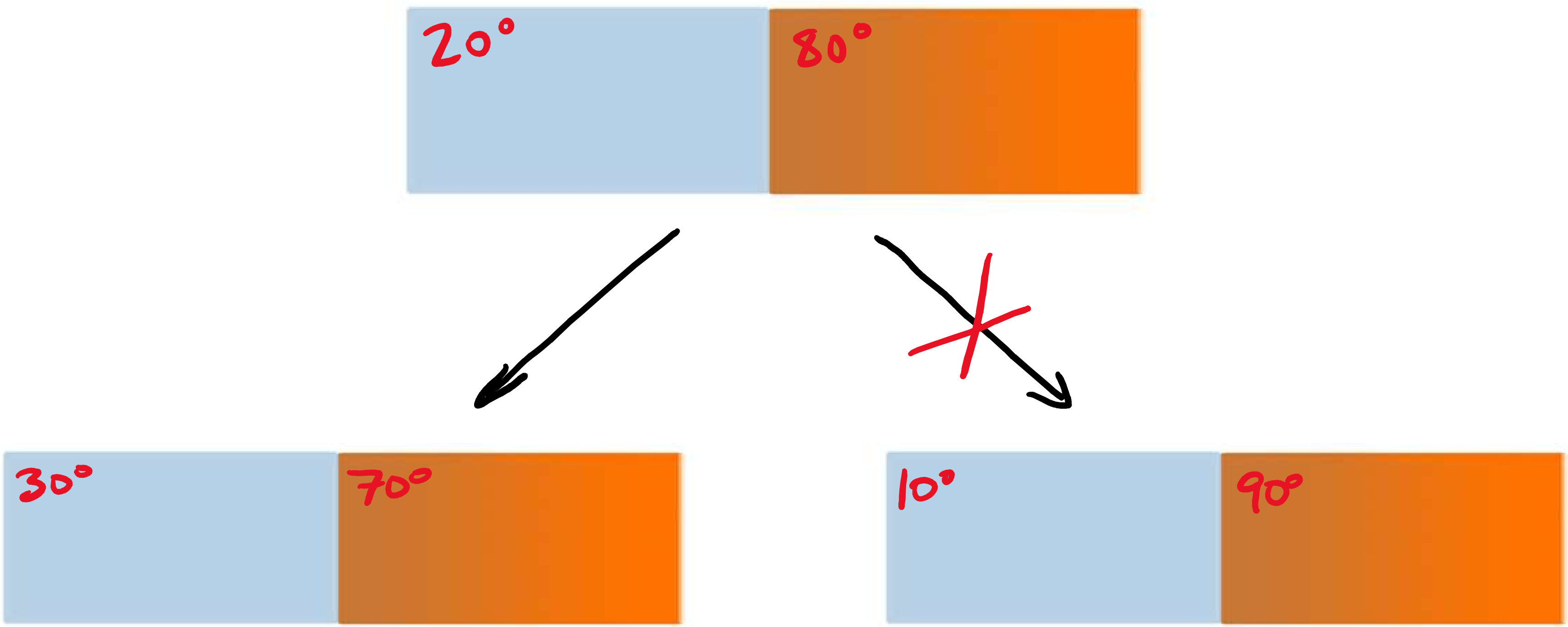
$$dS = \frac{dQ}{T}$$

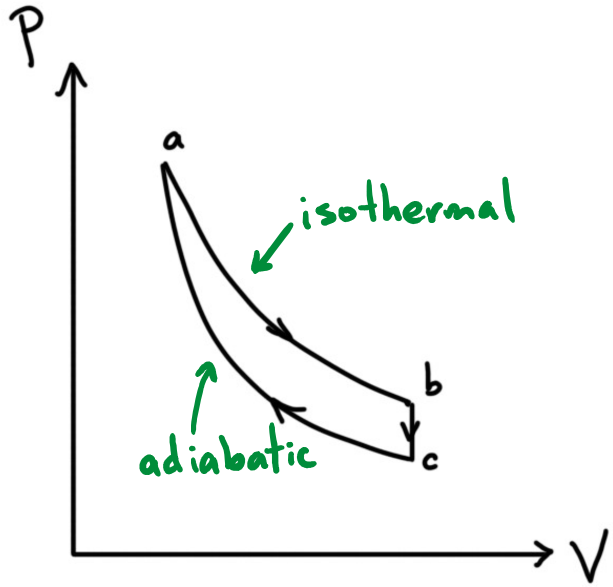
Violates 2nd Law so won't happen

2ND LAW OF THERMODYNAMICS:

Total entropy never decreases.

→ probability of decrease is too small to comprehend





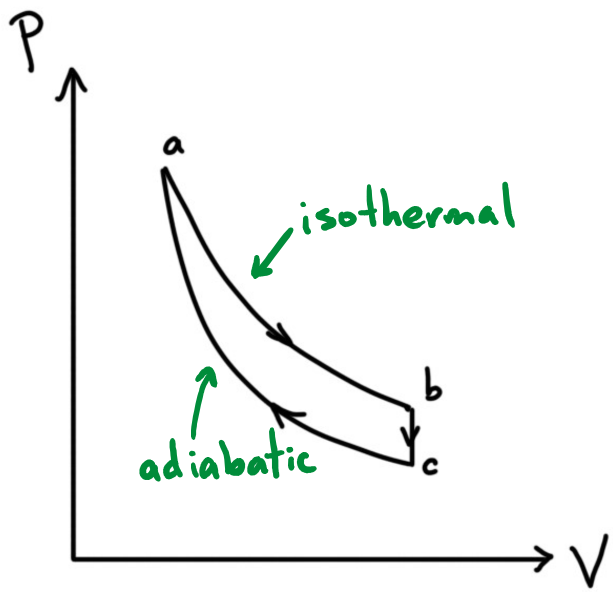
In the cycle shown, we can say that from c -> a,

A) The entropy increases

B) The entropy is constant

C) The entropy decreases

$$ds = \frac{dQ}{T}$$



In the cycle shown, we can say that from c -> a,

A) The entropy increases

B) The entropy is constant

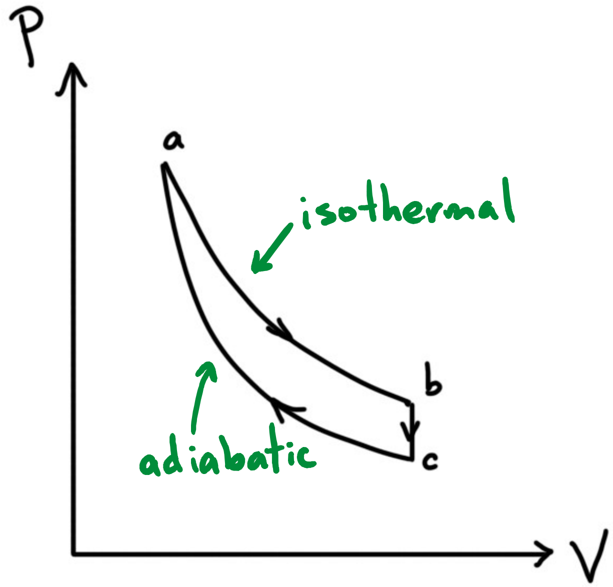
C) The entropy decreases

$c \rightarrow a$ adiabatic so $Q = 0$

$dQ = 0$ for each part so

$dS = 0$

$$dS = \frac{dQ}{T}$$



In the cycle shown, heat Q enters the gas in the isothermal step a -> b at temperature T. The entropy change during this step

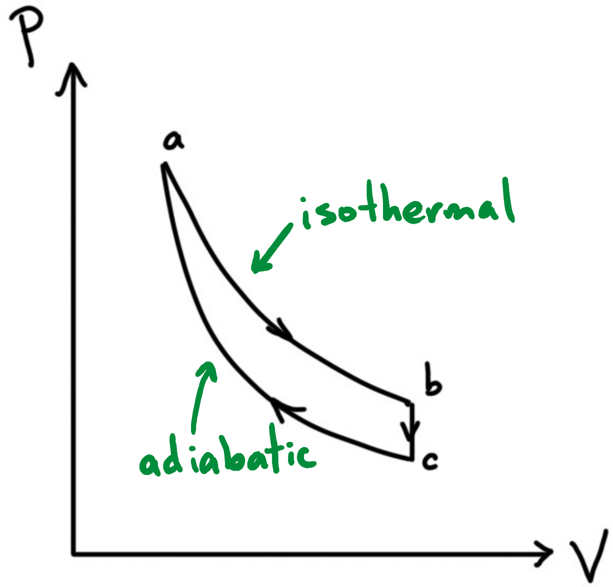
A) is equal to Q/T.

B) Is equal to 0.

C) is equal to -Q/T.

D) cannot be determined from the information provided.

$$dS = \frac{dQ}{T}$$



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A) is equal to Q/T.

B) Is equal to 0.

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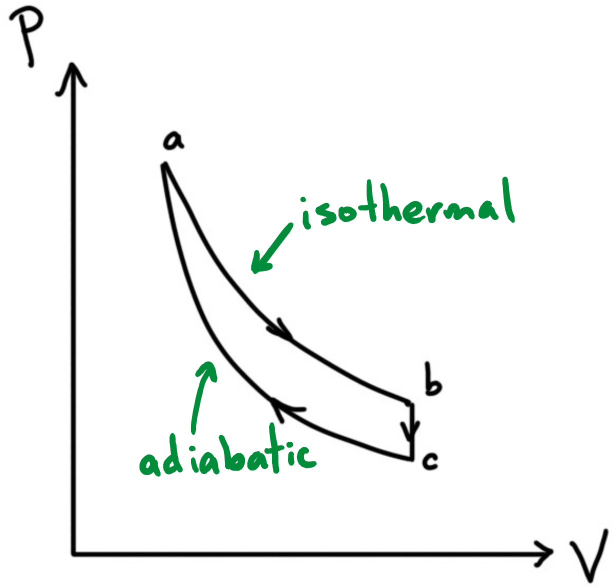
D) cannot be determined from the information provided.

T const. so

$$\Delta S = \frac{Q}{T}$$

$$dS = \frac{dQ}{T}$$



In the cycle shown, heat Q enters the gas in the isothermal step a -> b at temperature T. The entropy change from b -> c is

A) Q/T

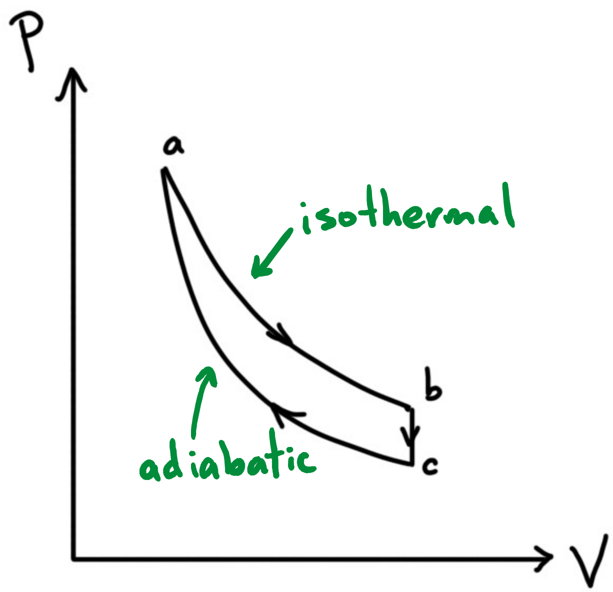
B) Between 0 and Q/T

C) 0

D) Between –Q/T and 0

E) -Q/T

$dS = \frac{dQ}{T}$



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A) Q/T

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C) 0

D) Between –Q/T and 0

E) -Q/T

$S_c = S_a$ since

$c \to a$ adiabatic

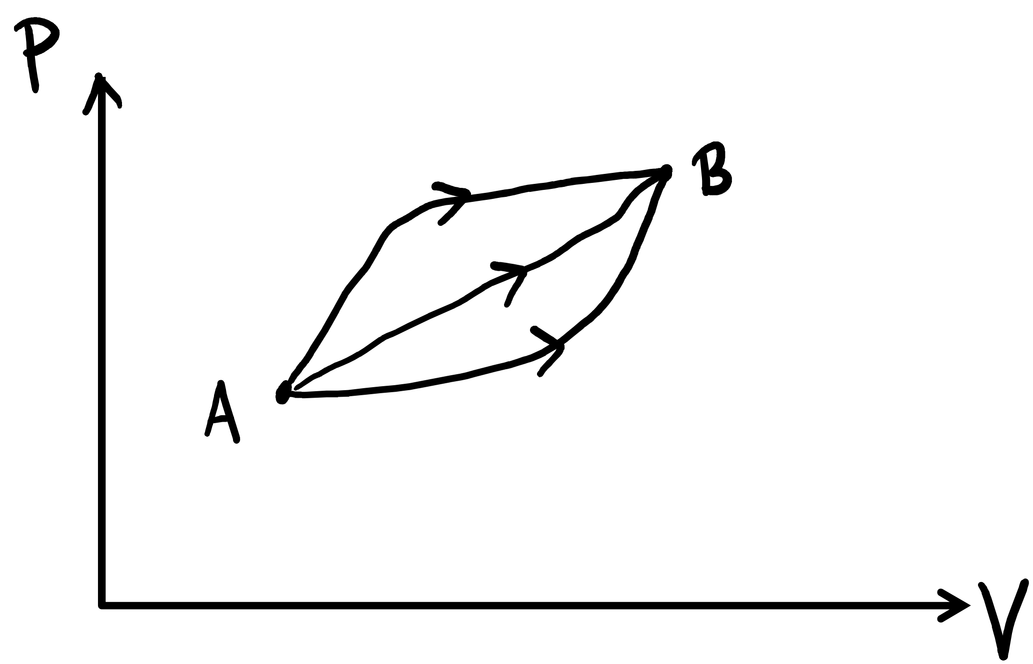
so $\Delta S_{a \to b} + \Delta S_{b \to c} = 0$

$\Delta S_{b \to c} = -\Delta S_{a \to b}$

$= -\dfrac{Q}{T}$

$dS = \dfrac{dQ}{T}$

Entropy is a state variable - like P, V, T, U



ΔS same for all paths, zero for cycle.

But: S for environment usually increases!